PATENT SPECIFICATION

(11) 1344681

1344681

(21) Application No. 36796/71 (22) Filed 5 Aug. 1971

(31) Convention Application No. 61905 (32) Filed 7 Aug. 1970 in

(33) United States of America (US)

(44) Complete Specification published 23 Jan. 1974

(51) International Classification B24D 3/34

(52) Index at acceptance
C4V 1 3

(19)

(54) RESIN BONDED ABRASIVE PRODUCTS

PATENTS ACT 1949

SPECIFICATION NO 1344681

The following amendments were allowed under Section 29 on 22 March 1983

Page 9 *after* line 22 *insert* In specification 1278184 there is described and claimed an abrasive element comprising grits of diamond or boron carbide in the cubic crystal form, said grits being metal coated and bonded by a bond containing an infusable organic resin, which includes a total filler content of 15% to 70% by volume of said bond which filler contains finely divided reinforcing filler which can be at least one metal of the group silver or copper and from 5 to 40% by volume of said bond of particulate graphite of particle size of from 1 to 300 microns.

Such abrasive tool is not claimed in the present patent.
Subject to the foregoing disclaimer:

THE PATENT OFFICE
23 May 1983

Bas 251380/4

... suitable for grinding hard tool steels.

Improvements of resinoid bonded diamond (or cubic boron nitride) abrasive tools has been recently achieved by the use of metal clad diamond grit or by the use of metal clad cubic nitride grit. The present applicants have found that finely divided graphite can be used in such tools in United States Application Serial No. 876,655, to improve significantly the performance in dry grinding. The present invention provides further improvement in performance through the use of particular combinations of particulate solid film lubricant fillers and silver or copper fillers.

The present invention involves modifying the bond of resinoid bonded abrasive tools, and provides an abrasive tool in which abrasive grits are bonded by an organic polymer bond, the abrasive grits are diamond or metal clad cubic boron nitride particles or both, and the bond contains from 10 to 60%, by volume, of finely divided metal filler which is silver, silver coated copper, or copper, or a combination thereof, in the presence of from 5 to 30% of a particulate dry film lubricant filler.

polymers disclosed in French Patent 1,455,514) have been introduced which have utility in bonding abrasive grains. These resins, like the cross linked resins discussed above, are infusible, as opposed to the more common thermoplastic linear polymers having definite softening ranges and which are reversibly softenable. Examples of such resins, having utility in making abrasive tools, are given in United States Patent 3,329,489 (polybenzimidazole), and United States Patents 3,295,940 and 3,385,684 (polymides). Polysulfide resins such as disclosed in United States Patent 3,303,170 and polypyrrolidones may also be employed. For use in making coated abrasive discs or belts liquid resin systems may be preferred, while for bonded abrasives solid powdered resins can be used.

When the abrasive, diamond grit, or cubic boron nitride, has a metal coating encapsulating the abrasive grit the metal is preferably present in the coated particle in an amount between 10 and 70%, by volume. The provision of a metal coating is essential when the abrasive is cubic boron nitride. Uncoated diamonds can

SPECIFICATION AMENDED - SEE ATTACHED SLIP

PATENT SPECIFICATION

(11) 1344681

1344681

(21) Application No. 36796/71 (22) Filed 5 Aug. 1971
(31) Convention Application No. 61905 (32) Filed 7 Aug. 1970 in
(33) United States of America (US)
(44) Complete Specification published 23 Jan. 1974
(51) International Classification B24D 3/34
(52) Index at acceptance
C4V 1 3

(19)

(54) RESIN BONDED ABRASIVE PRODUCTS

(71) We, NORTON COMPANY, a corporation organized under the laws of the State of Massachusetts, United States of America, of 1 New Bond Street, Worcester, State of Massachusetts, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to abrasive tools, in particular grinding wheels and coated abrasive belts, containing the hardest known abrasives, diamond and cubic boron nitride which, when metal coated diamond grit is the primary abrasive are particularly suitable for the dry grinding of cemented carbide tool material (e.g. cemented tugsten carbide), and when metal coated boron nitride grit is the primary abrasive are particularly suitable for grinding hard tool steels.

Improvements of resinoid bonded diamond (or cubic boron nitride) abrasive tools has been recently achieved by the use of metal clad diamond grit or by the use of metal clad cubic nitride grit. The present applicants have found that finely divided graphite can be used in such tools in United States Application Serial No. 876,655, to improve significantly the performance in dry grinding. The present invention provides further improvement in performance through the use of particular combinations of particulate solid film lubricant fillers and silver or copper fillers.

The present invention involves modifying the bond of resinoid bonded abrasive tools, and provides an abrasive tool in which abrasive grits are bonded by an organic polymer bond, the abrasive grits are diamond or metal clad cubic boron nitride particles or both, and the bond contains from 10 to 60%, by volume, of finely divided metal filler which is silver, silver coated copper, or copper, or a combination thereof, in the presence of from 5 to 30% of a particulate dry film lubricant filler.

By bond is meant the polymeric bond of an abrasive inflexible product known sometimes in the art as a bonded product and the polymeric adhesive coating used in flexible products to bond abrasive to backing.

Known synthetic resins useful in making coated or bonded abrasives may be employed in the present invention. Obviously, strength and heat resistance are necessary properties. The well-known cross linked resins such as phenol-aldehyde resins, melamine-aldehyde resins, urea-aldehyde resins, polyester resins, and epoxy resins, including the epoxy novolacs, may be used and conventional modifiers and plasticizers may be used. Part of the filler content may consist of conventional particulate fillers such as silicon carbide. Fairly recently, new essentially linear polymers as well as thermoset polymers (such as thermoset polymers disclosed in French Patent 1,455,514) have been introduced which have utility in bonding abrasive grains. These resins, like the cross linked resins discussed above, are infusible, as opposed to the more common thermoplastic linear polymers having definite softening ranges and which are reversibly softenable. Examples of such resins, having utility in making abrasive tools, are given in United States Patent 3,329,489 (polybenzimidazole), and United States Patents 3,295,940 and 3,385,684 (polymides). Polysulfide resins such as disclosed in United States Patent 3,303,170 and polypyrrolidones may also be employed. For use in making coated abrasive discs or belts liquid resin systems may be preferred, while for bonded abrasives solid powdered resins can be used.

When the abrasive, diamond grit, or cubic boron nitride, has a metal coating encapsulating the abrasive grit the metal is preferably present in the coated particle in an amount between 10 and 70%, by volume. The provision of a metal coating is essential when the abrasive is cubic boron nitride. Uncoated diamonds can

be used, however, and tools employing them are considered part of the present invention. Metal coated diamonds are disclosed in Soulard French Patent 1,142,688, Belgian Patents 683,508 and 698,428, and French Patent 1,522,735. Possible metal coatings are copper, silver, nickel, cobalt, molybdenum and, in general, any metal melting above about 500° F. which is chemically stable in the grinding tool. Although, for wet grinding the volume per cent of metal coating can be higher, for dry grinding, to which the tool of the present invention is particularly directed, the volume per cent of metal coating should be between 10 to 60%, by volume.

Coated diamonds are commercially available which have nickel coatings within the above range of 10 to 50%, by volume, and copper coatings, within the same range. These coatings can be produced by electrodeposition on a thin, silver coating produced by chemical deposition on the grits. Thus the coatings need not be a single metal, only, and a wide variety of metal coatings are possible and useful in the present invention. Alloys of the metals are also useful.

The grit size of the abrasive is not generally relevant to the present invention, but grit sizes of 60 through 320 (based on the uncoated grit) are commonly used in diamond wheels. All grit sizes referred to herein are U.S. Standard Sieve sizes.

Grinding elements according to the present invention may be formed by pressing the mixture in a mold of the desired shape. The mold may be heated and the resin may be completely or partially cured in the mold.

Figure 1 shows a perspective view of a grinding element; and

Figures 2 and 3 show a perspective view of the grinding element of Figure 1 mounted for use in two different mountings.

Figure 1 shows a typical grinding element 10. Figure 2 shows the grinding element mounted on a core 20 to produce a straight grinding wheel. Figure 3 shows the element 10 mounted on a cup shaped support to form a grinding wheel commonly referred to as a "cup wheel." A suitable material for making the support member is an aluminum-filled resin as disclosed in United States Patent 2,150,886. The tool may be molded directly onto the support, the support may be molded onto the tool, or the tool may be cemented onto the support after fabrication.

For the production of coated abrasive discs or belts, a liquid phenol-formaldehyde resin can be used. A size coat of liquid resin should be employed after the maker coat, and at least the size coat should contain the fillers of this invention. The size should be "high," that is, it should extend from the maker coat to close to the tips of the abrasive so that the fillers in the coat contact the work during grinding.

The required fillers of the present invention are:

(1) silver or copper or a combination such as silver coated copper, present in the bond in the amount of from 10 to 60% by volume, preferably 30 to 50%, and

(2) a solid dry-film lubricant present in the bond in the amount of from 5 to 30%, by volume, and preferably from 10 to 20%.

Silver is significantly better than copper, and silver coated copper is better than copper. Although the exact particle size range is not critical, the finer metal powders are more effective. Typical powder are 325 mesh and finer and may measure 1 to 10 microns in size, by conventional microscopic examination. When copper is employed, deoxidized powders should be used.

The lubricant filler may be one of the known inorganic materials such as graphite, fluorinated graphite, metal coated graphite (United States Patent 3,402,035) hexagonal boron nitride, tungsten disulfide, molybdenum disulfide, niobium diselenide, and tungsten diselenide, all of which have been effective in the present invention to give a grinding efficiency at least 200% of a standard test wheel containing a silicon carbide filler only. All of these materials are crystalline and have a layer-lattice structure in which the bonding between layers is by relatively weak Van der Waal's forces.

Organic dry-film lubricants are finely divided solid polymeric materials. Suitable materials are extrusion grades of acrylonitride-butadiene-styrene terpolymers, acetal copolymers (polyformaldehyde), chlorinated polyethers, polytetrafluorotrifluoroethylene, fluorinated ethylenepropylene copolymers, polyvinylidene fluoride, ionomers, nylons, polyphenylene oxides, polyvinyl chloride, polyvinylidene chloride, polycarbonates, polyesters including thermoplastic polyesters and flexible polyesters, polyethylene, polysulfones, styrene-butadiene copolymers, and polyurethanes.

In addition to the metal and dry-film lubricant powder fillers, and inert fillers such as silicon carbide may be added to improve the strength of the bond or otherwise control its physical properties. Where lower diamond concentrations are employed it may be desirable to add such fillers to reduce the overall bond content of the tool or grinding element.

Normal process steps, conventional in the art, can be used to fabricate the wheels, discs, or belt according to the present invention.

A preferred bond mix for making a bonded abrasive ring for mounting on a backing element, such as shown in the drawing is as follows:

PHENOLIC BOND MATERIAL

	Parts by Weight	Parts by Volume
Powdered Phenol-aldehyde pre-polymer (BRP 5980 available from Union Carbide Corporation which includes 9% hexamethylene tetramine and to which 10% by weight of lime is added	17.3	45.2
Silver powder (Metz Refining Co. C—18)	58.6	20
Polytetrafluoroethylene powder (Liquid Nitrogen Processing Co. TL—115)	6.0	10
Silicon Carbide (800 grit)	15.8	17.7
Furfural	2.3	7.1

In making a bonded abrasive tool employing the above mix, the abrasive (diamond or metal clad boron nitride) is wet with the furfural and the mixture of bond and fillers is added and mixing continued to form a homogeneous batch. Sufficient of the mix is then placed in a mold of the desired shape and the mix is hot-pressed to shape. Normally, using the above bond, the tool is then removed from the mold and further cured in an oven. Typical molding conditions are a pressure of 5 tons per square inch, a temperature of 160° C, and a molding time of 20 minutes. The final cure can be carried out in an air atmosphere oven for 24 hours at 175° C. Control of the temperature of the final cure is effective, as is well known in the art, in controlling the hardness or grade of the bond which may differ depending upon the specific application.

The cured abrasive element is attached to a core or holder, as is conventional in the art, to produce a grinding tool such as shown in Figures 2 and 3 of the drawing. In the tabulated examples below, cup type wheels were employed of the dimensions and standard indicated. All the tests were run dry (no liquid coolant).

Where other resin systems are employed than the phenolic bond given above, it is known in the art that different curing or processing temperatures may be required. For example, in the case of the polyamide resins, typical fabrication conditions would be a pressure of 10 tons per square inch, and a hold at 270° C. for 15 minutes. No post cure is required. A commercial polyamide available from Rhone-Poulenc, identified as P.I.—M33A, cured under these conditions, and containing 50% silver filler and 10% polytetrafluoroethylene as fillers, gave a grinding efficiency of 202%, or 102% above the control wheel, in a test similar to that of Table I. A second test with a different polyamide identified as P.I.—M33B, gave a grinding efficiency of 293% under identical conditions where 40% silver and 10% TFE fillers were used.

EXAMPLES.

The following test was made on wheels made with the Phenolic Bond Material described above, the amounts of fillers and resin, however, being varied as indicated. The wheels were cup wheels, 6A9 type, 4"×1¾"×1¼". The diamond was coated with 56 weight per cent nickel and was 150 grit (Uncoated), and the wheels contained 17% diamond by volume. The work ground on a modified surface grinder was a cemented tungsten carbide, the unit infeed was 2.5 mils. Grinding conditions and the work piece were the same for all the wheels. The first wheel listed was a standard commercial wheel containing 35% by volume of silicon carbide in the bond. Table I give the results. The " wheel no." is for identification purposes, G is the grinding ratio or grinding efficiency expressed as a ratio of the volume of carbide removed from the workpiece to the volume of wheel worn away, P is the average power drawn by the wheel in watts, and %G and %P give the %'s in terms of the standard comparison wheel. TFE stands for polytetrafluoroethylene.

TABLE I

Wheel No.	G	P	%G	%P	Filler Level (% of bond) SiC	Ag	TFE
18617	36.2	1390	100	100	35	0	0*
18577	33.0	950	91	68	25	0	10*
18578	36.9	1085	102	78	37.7	0	10*
18580	74.5	1215	205	87	5	20	10
18641	96.6	1180	266	85	17.7	20	10
18583	47.2	1350	130	97	20	10	5
18584	46.7	1095	129	78	10	15	10
18593	36.4	1380	100	99	20	15	0*

*Comparative Tests

The above results show that the lubricant filler alone, at the 10% level, does not significantly improve the grinding efficiency, although the power is substantially reduced. Similarly the metal, alone, at the 15% level produces no significant improvement. But combined, at these levels, the efficiency is significantly improved and the power is significantly reduced. Best results, in this test, were shown with 20% silver and 10% polytetrafluoroethylene. The results thus show a synergistic effect when the two fillers are employed together in the bond, which would not be expected from the results obtained when only silver or only polytetrafluoroethylene are employed.

The test results given in Table II compare the results for wheels of various levels of fillers with a standard wheel like that of Table I, but containing a slightly higher level of silicon carbide filler. The diamond was 150 grit, nickel coated, except for the diamond in the last two wheels which was copper coated in the amount of 50 weight per cent. The infeed was 2.5 mils on cemented tungsten carbide workpieces. The carbide materials and the grinding conditions were the same for all wheels.

TABLE II

Wheel No.	G	P	%G	%P	Filler Level SiC	Ag	TFE
18664	47.6	1425	100	100	40	0	0*
18665	78.5	1120	165	79	10	20	10
18666	89.6	975	188	68	5	20	15
18667	87.7	1180	184	83	5	25	10
18668	95.2	1020	200	72	0	25	15
18669	147.5	1280	312	90	0	30	15
18670	108.5	1090	228	76	0	30	15
18671	91	1120	191	79	10	20	10
18672	75.3	960	158	67	5	20	15

*Comparative Test

The conclusions drawn from this test are that the optimum silver content is over 30%, 15% TFE is better than 10% from the standpoint of power drawn, and nickel and copper coated diamond are similar in performance when 20% silver filler is employed.

The following results were obtained on a different, somewhat more rigid machine than the previous tests. Otherwise the test conditions were essentially the same, but a different cemented tungsten carbide sample was employed in the workpieces. This test evaluated silver contents of 10 to 20% with no lubricants and silver contents of 10 to 20% combined with 15 to 25% graphite.

TABLE III

Wheel No.	G	P	%G	%P	Filler Level % SiC	%Ag	% Graphite
18713 (control)	26	1075	100	100	40	0	0*
18714	38	750	146	70	15	10	15
18715	39	625	150	58	5	10	25
18716	32	775	123	72	10	15	15
18721	29	775	112	72	0	20	25
18722	23	1075	89	100	30	10	0*
18723	19	975	73	68	25	15	0*
18724	22	1000	85	93	20	20	0*

*Comparative Test.

Table IV gives the results of a test wherein silver contents of 30 to 50%, with a solid film lubricant filler, were compared to a standard wheel and to a wheel containing graphite only. As in the previous tests, the wheels were all run on the same sample of carbide and under the same test conditions. The infeed was 2.0 mil. The diamond was present in the amount of 11% by volume in the wheels, instead of 17% as in the previous tests, and was nickel clad, except for the diamond in wheel 84 which was copper clad.

TABLE IV

Wheel No.	G	P	% G	%P	Ag	Filler Levels		
						TFE	Graphite	SiC
47 (control)	17.4	1025	100	100	0	0	0	35*
51	22.6	765	130	75	0	10	20	15*
82	63.6	1135	365	111	40	10	0	0
84	79.8	1190	459	116	50	10	0	0
84	67.8	925	390	90	50	10	0	0
85	44.0	840	253	82	30	0	20	0
86	43.1	840	248	82	40	0	20	0

*Comparative Test.

At 2.5 mil. infeed the relative results were similar except that wheels 84 and 86 were unsatisfactory under the higher infeed in that they loaded, chipped, and drew high power. Wheel 82 appeared best for general use.

In the following test silver filler was compared with silver coated copper. The wheels all contained 11% by volume of diamond, and the diamond was nickel clad. The unit infeed was 2.0 mils. The results were as follows:

TABLE V

Wheel No.	G	P	%G	%P	Ag	TFE	Ag on Cu	SiC
Control	17.8	875	100	100	0	0	0	35
950	28.9	825	162	162	94	15	0	0
951	29.6	800	166	91	45	15	0	0
956	29.2	750	164	86	0	15	45	0

Although this test showed that Ag and Ag coated Cu are equivalent, more sensitive testing has indicated the superiority of Ag over Ag coated Cu.

In the grinding of high-speed steels, wheels employing metal clad 150 grit cubic boron nitride were compared with various filler contents. The unit infeed was 2.0 mils. and the wheels were the same shape and dimensions as in the tests reported above.

The filler content of the wheels was as follows:

TABLE VI

Wheel No.	SiC	Al_2O_3	Ag	TFE	Graphite	
80B	20	20	0	0	0	Comparative Tests
81B	35	0	0	0	0	
82B	15	0	0	0	20	
83B	28	0	0	0	20	
85B	0	0	40	0	15	

The test results on M3, M43, and T15 high-speed steel workpieces were as follows:

TABLE VII

Wheel No.	M3				M43				T15			
	G	P	%G	%P	G	P	%G	%P	G	P	%G	%P
80B	21.8	625	100	100	39.2	500	100	100	3.0	675	100	100
81B	32.8	500	150	83	15.1	475	39	95	5.4	450	180	78
82B	22.7	425	104	71	19.6	350	50	70	8.8	400	293	70
83B	38.7	425	177	71	32.7	400	83	80	12.1	450	403	78
85B	58.6	450	269	75	57.3	425	147	85	22.9	425	765	74

Based on the most reproduceable testing methods, gained from the above tests, a variety of metal and solid lubricant combinations were employed. Grinding efficiencies of at least 40% above the standard were achieved with the metal silver, copper, or silver coated copper with various fillers, as listed below in table VIII and grinding efficiencies lower than the standard control wheel were achieved with nickel, molybdenum, iron, tin, and aluminum fillers.

TABLE VIII

Wheel No.	G	%G	P	%P	Metal	Lubricant
19083	42	410	1200	120	Ag	Bn
19076	39.5	383	1150	115	Ag	TFE
19086	35.9	348	1250	125	Ag	WS_2
19229	30.8	299	1350	135	Ag	NB Nickel Coated
19089	30.5	296	1400	140	Ag	Graphite
19085	27.9	271	1150	115	Ag	MoS_2
19088	27.8	270	1150	115	Ag	Polyethylene
19084	26.3	255	1350	135	Ag	$NbSe_2$
19087	20.2	196	1100	110	Ag	WSe_2
19077	14.4	140	1150	115	Cu	TFE
19231	11.9	116	1000	100	Mo	MoS_2
19257	10.7	104	850	85	—	Graphite
19252	10.3	104	1000	100	Control Wheel 35% SiC	
19078	9.3	90	950	95	Ni	TFE
19082	7.5	73	800	80	Mo	TFE
19228	6.4	62	850	85	Mo	TFE
19081	5.8	56	850	85	Fe	TFE
19079	5.4	52	900	90	Al	TFE
19080	4.4	43	800	80	Sn	TFE
19230	3.2	31	750	75	Al	TFE

A large variety of organic fillers, in the form of a finely divided powder were prepared and tested at the 10 and 15% levels in the bond, in combination with 40% of fine silver in the bond. The following gave improvement in G of from 2½ to 5 or more times that of a similar wheel omitting the organic filler, but including 40% silver: styrene-butadiene (" 56B " Pliolite from Goodyear Company, from 85% styrene by weight and 15% butadiene): acrylonitrile-butadiene-styrene (Lustran 1—410—1000 supplied by Monsanto) styrene-acrylonitrile (Lustran A—21—2020 from Monsanto, 71% styrene, 21% acrylonitrile); polyurethane (Estane Type 58105 from Goodrich): polyvinyl chloride (Geon 92 from Goodrich) acetal (Delrin from DuPont): polysulfone (Union Carbide TXRP 2044); polyurethane (made from 83% adiprene L—167, and 17% by weight of 4—4′ methylene-bis (2 chloroaniline), Adiprene being a liquid diisocyanate reaction product with a polyalkylene ether glycol, available from DuPont): nylon (DuPont Zytel), and polycarbonate (General Electric Lexan). " PLIOLITE," " GEON," " DELRIN," " ZYTEL," " LUSTRAN " and " ADIPRENE " are Registered Trade Marks.

To show the improvement obtained using non-metal clad diamond phenolic bonded wheels were compared in dry carbide grinding as follows, employing uncoated diamond:

	Filler	G	Power
Control Wheel	35% SiC	21	1200 watts
Test Wheel	40% Ag, 10% PTFE	97	1100 watts

Thus, in comparing with wheels employing uncoated diamond the invention wheel is almost 5 times as efficient, with a lower power draw.

Although instances have been found of solid powdered organic polymers, which do not improve wheel performance, that is do not function as solid lubricants, when employed according to this invention, this selection of an operative polymer from one of those disclosed generically or specifically herein, or an obvious equivalent, is a simple matter for one skilled in the art, involving at most, in the case of equivalent materials, the manufacture and testing of a wheel containing such material.

Throughout the specification the volume % of fillers in the bond means the parts of filler per hundred parts of total bond solids, including fillers, but not including abrasive particles and not including the metal cladding on the abrasive.

WHAT WE CLAIM IS:—

1. An abrasive tool in which abrasive grits are bonded by an organic polymer bond, the abrasive grits are diamond or metal clad cubic boron nitride particles or both, and the bond contains from 10 to 60%, by volume, of finely divided metal filler which is silver, silver coated copper, or copper, or a combination thereof, in the presence of from 5 to 30% of a particulate dry film lubricant filler.

2. An abrasive tool according to claim 1, in which the metal filler is present in an amount of from 30 to 50%, by volume, and the dry film lubricant filler is present in an amount of from 10 to 20% by volume.

3. An abrasive tool according to either of claims 1 and 2, in which the dry film lubricant is an organic crystalline material having a layer-lattice structure in which the bonding between atoms in an individual layer is by strong covalent or ionic forces, while the bonding force between layers is by relatively weak Van der Waal's forces or an organic polymer.

4. An abrasive tool according to any one of claims 1 to 3, in which the dry film lubricant is MoS_2, WS_2, WSe_2, $NbSe_2$, graphite, fluorinated graphite, hexagonal boron nitride, polytetrafluoroethylene, polyethylene, polychlortrifluoroethylene, fluorinated ethylene-propylene copolymers, nylon, polycarbonate, polysulfone, styrene-butadiene copolymers, acrylonitrile-butadiene-styrene terpolymers, styrene-acrylonitrile, polyurethane, polyvinylchloride, polyformaldehyde, or polyester polymers.

5. An abrasive tool according to any one of claims 1 to 4, substantially as hereinbefore described in the Examples.

For the Applicants,
A. POOLE & CO.,
Chartered Patent Agents,
19, Devonshire Street, London, W1N 2BJ.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1974.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

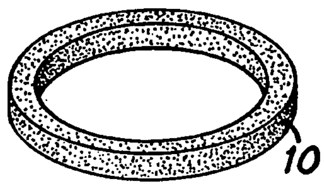

FIG. 1

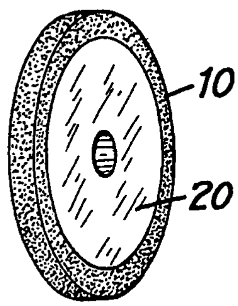

FIG. 2

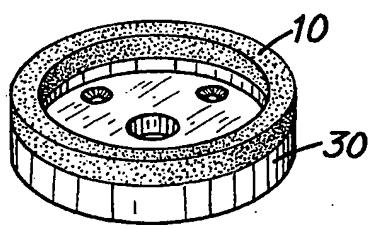

FIG. 3